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FROM TILLAGE TO TABLE: THE INDIGENOUS CULTIVATION OF GEOPHYTES FOR FOOD IN CALIFORNIA

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ABSTRACT.—One of the oldest forms of tillage in the world is the digging of subterranean organs of wild plants for food and other purposes. Many areas were managed for increased densities and abundances of wild plants with edible corms, bulbs, tubers, and rhizomes. The horticultural techniques of digging, replanting, and sparing, in conjunction with larger-scale habitat management, created ecological effects at the species, population, community, and landscape levels. California provides a vivid example of an area where tillage was an important element in a comprehensive land management system that was in place for millennia. It is hypothesized that native California tillage activities mimicked natural disturbances with which plants coevolved, and played an ecological role that is now vacant in many wildlands, where Native Americans can no longer harvest and manage plants. Their land management system needs to be studied, described, interpreted, and experimentally mimicked to better understand indigenous disturbance regimes. It is suggested that some wildland areas would benefit from the reintroduction of management and harvesting regimes that authentically mimic indigenous techniques.

RESUMEN.—Una de las formas más antiguas de labranza en el mundo fue excavar los órganos subterráneos de plantas silvestres para obtener alimento y para otros propósitos. Muchas áreas fueron manejadas para incrementar la densidad y abundancia de plantas silvestres con cormos, bulbos y tubérculos comestibles. Las técnicas hortícolas de escarbar, replantar y dejar plantas para que proliferen, junto con el manejo del hábitat a mayor escala, crearon efectos ecológicos al nivel de especie, población, comunidad y paisaje. California ofrece un ejemplo elocuente de un área donde la labranza fue un elemento importante en un sistema integral de manejo del terreno que operó a lo largo de milenios. Se plantea como hipótesis que las actividades de labranza de la población indígena de California simulaban las perturbaciones naturales con las cuales habían coevolucionado las plantas, y que jugaban un papel ecológico ahora vacante en muchas áreas naturales, donde los indigenas ya no pueden cosechar y manejar las plantas. Sus sistemas de manejo del terreno deben ser estudiados, descritos, interpretados y reproducidos experimentalmente para entender mejor los regímenes indígenas de perturbación. Se sugiere que algunas áreas naturales se beneficiarían de la reintroducción de regímenes de manejo y cosecha que imitaran las interacciones indígenas de una manera auténtica.

RÉSUMÉ.—Une des plus anciennes formes de labourage au monde consistait à fouiller la terre pour en extraire les organes souterrains des plantes sauvages utilisés comme aliments ou à d'autres fins. Plusieurs endroits étaient gérés afin

d'augmenter en densité et en abondance les plantes sauvages qui comportaient des rhizomes, des bulbes et des tubercules comestibles. Les techniques d'horticulture d'extraction, d'ensemencement et de jachère associées à une gestion de l'habitat à grande échelle a produit des effets écologiques aux niveaux de l'espèce, de la population, de la communauté et du paysage. La Californie fournit un exemple frappant d'un endroit où le labourage était un élément important dans un système global de gestion des terres, en place depuis des millénaires. Nous émettons l'hypothèse que les activités de labourage des Amérindiens de la Californie mimaient les perturbations naturelles du milieu où coévoluaient les plantes et ont joué un rôle écologique qui maintenant fait défaut à plusieurs terres sauvages où les autochtones d'Amérique ne peuvent désormais plus récolter et gérer les plantes. Leur système de gestion des terres doit être étudié, décrit, interprété et mimé de façon expérimentale afin de mieux comprendre les régimes de perturbation autochtones. Il est suggéré que quelques endroits sauvages pourraient bénéficier d'une réintroduction des régimes de gestion et de récolte qui mimeraient de façon authentique les interactions autochtones.

INTRODUCTION

The digging of underground plant parts for food is still a common activity in many indigenous societies around the world. The Dena'ina of south-central Alaska, for example, dig the edible tubers of Alaska carrots (*Hedysarum alpinum*) with a moose leg bone or horn, cut off the thick end of the tuber, and then bury it to insure that more potatoes will grow (Kari 1987:127). The Tarahumara of the mountains of Chihuahua gather wild onions (*Allium* spp.) with a digging stick, then release the lateral daughter bulbs to perpetuate the plant (Bye 1985). The Australian aborigines of Victoria still dig up the tubers of *murnong* (*Microseris scapigera*), and gathering areas historically were burned over to increase production (Gott 1983). The Indians of the Pacific Northwest selectively harvest camas (*Camassia* spp.) bulbs, leaving the smaller ones behind for future harvests (Turner and Kuhnlein 1983:241). In California, these underground swollen stems (known as bulbs, corms, tubers, or rhizomes) traditionally provided a very important source of carbohydrates, vitamins, minerals, and fiber in the diet. Today, there are a small number of harvesters in some California tribes that still gather edible bulbs and corms, spare whole plants, and replant cormlets and bulblets to allow for future regeneration (Anderson 1993). In the anthropological literature on California the generic term applied to these plants was "Indian potatoes" or "root-crops." In the botanical literature they are called geophytes—vascular plants that die back to underground storage organs during periods unfavorable for growth (Rundel 1996).

Embedded within such plant-human interactions were ancient horticultural techniques, adopted cross-culturally, that ensured long-term harvests of wild geophytes. It is hypothesized that even before the full development of agriculture, humanity's relationship with edible geophytes had already shifted from one of predation to one of mutualism. Over long periods of time, tillage, selective harvesting, and burning had subtle, yet nonetheless profound, ecological impacts at the species, population, community, and landscape levels within a multitude of habitats in different parts of the world. Digging up the subterranean organs of wild plants for foods was perhaps the oldest form of tillage, one that became the

precursory management technique and the ecological foundation for the development of root crop agriculture in some areas. The digging of subterranean plant parts was traditionally a female responsibility in most North American cultures, and the role of women in vegetation management in North America has often been undervalued and underrecorded (Hunn 1981; Hunn and French 1981).

Some of the best evidence for such management comes from California, where root crops were a staple food in almost every indigenous society. These cultures utilized fire, the sparing of plants, the replanting of propagules, and other techniques to promote desired densities and to perpetuate high population levels of certain species. The management of diverse geophytes for food in California has been selected as an example that suggests the sophistication and complexity of past resource management systems that probably shaped the ecology of wildlands in California. This paper provides an overview of the role of geophytes in California's indigenous subsistence economies, the horticultural practices that were applied to "wilderness" areas, and the potential associated ecological effects that might have resulted from them. It then identifies three types of research that are needed to reconstruct the details of this interaction: ethnobotanical research, observational studies, and field experiments.

INDIAN USES AND HARVESTING OF GEOPHYTES

From the northwestern coasts to the southeastern deserts, "root-crops" comprised a dietary staple in almost every region of California (Barrett and Gifford 1933; Chesnut 1902; Driver and Massey 1957). The vegetational resources of California helped sustain some of the highest native population densities in North America (Heizer and Elsasser 1980). Geophytes were utilized for food, dyes, glues, medicines, and other purposes (Figures 1, 2), although only food uses are consid-

FIGURE 1.—An unidentified Native American couple from California digging the tuber of *Lomatium californicum,* probably used medicinally and ceremonially.

FIGURE 2.—A close-up view of the medicinal tuber of *Lomatium californicum*. Photograph taken by J.P. Harrington, courtesy of the Santa Barbara Museum of Natural History.

FIGURE 3.—The bulbs of mariposa lilies (*Calochortus* spp.) were once eaten by numerous California Indian tribes. Photograph by Kat Anderson.

FIGURE 4.—The corms of golden brodiaea (*Triteleia ixioides*) were dug in the central Sierra Nevada by the Sierra Miwok. Photograph by Kat Anderson.

ered here. The most prominent genera that were gathered for their edible underground swollen stems in California included *Allium, Brodiaea, Calochortus, Camassia, Chlorogalum, Dichelostemma, Lilium, Perideridia, Sanicula,* and *Triteleia* (Figures 3, 4).

The harvesting of edible geophytes was accomplished with a hardwood digging stick, often fire-hardened for additional strength. After European contact, gatherers began to use a pointed iron bar with a handle, a modern adaptation of the wooden digging stick (Fowler 1986). The digging of plant parts for food was generally the task of women, but sometimes communal gathering parties of whole families were organized to participate in exceptionally important plant harvests (e.g., the Sierra Miwok; Barrett and Gifford 1933). Tubers and bulbs were (and continue to be) harvested in the spring before flowering, during flowering, and during seeding, depending upon species, use, tribe, and individual family. Oral interviews conducted by myself (Anderson, interview notes, unpublished), Heffner (1984), and others confirm that some edible underground parts are still harvested today by some gatherers in various tribes (Figure 5).

FIGURE 5.—The delicate-tasting tubers of *Sanicula tuberosa* are still gathered among the tall ponderosa pines by the Southern Sierra Miwok in the Sierra Nevada and eaten raw. Photograph by Kat Anderson.

The extreme importance of geophytes in the subsistence economies of native groups is reflected in their inclusion in lunar calendars, in special ceremonies that honored these ethnobotanically important plants, and in their mention in the mythologies of various tribes (Schulz 1954:60). For example, in the Pomo lunar calendar, the month of ***butich-da*** (June) was named for the mature bulbs of a unidentified species in the *Brodiaea* complex (Kroeber 1925:209). In one Bear River tale, Coyote leads his grandmother to a place where there are plenty of potatoes; she takes her digging stick and goes with him and begins digging. According to a Northeastern Maidu creation story:

> "The creator walked upon the new made world, creating living things.... As he sat resting and eating he took what remained of plants he had been eating and cast them across the meadows and said that was the place where Indians would dig roots" (McMillin 1963).

The food offered to early missionaries and explorers frequently consisted of bulbs of *Chlorogalum* and corms in the *Brodiaea* complex (Latta 1977: 65; Kroeber 1925:277). Bulbs were also sometimes recorded as emergency back-up foods during lean acorn years (Powers 1877:423).

DECLINING GEOPHYTE POPULATIONS

A number of the edible geophytes that traditionally have been important in the subsistence of California Indians are declining in population size and density in the areas where Indians used to gather them. The Paiute of Surprise Valley in northeastern California commented in the early 1930's that, "Nowadays there is little root gathering, one very good reason being that the plants are no longer to be found" (Kelly 1932:101). In 1938, ethnographer Gladys Nomland reported that the Bear River Indians of northwestern California could no longer gather camas, as a result of the cultivation of fields, and stock grazing (Nomland 1938). According to Roger Raiche (personal communication 1988),[1] blue camas used to be more common in the San Francisco Bay area, but is now hard to find. The decline of this and other geophyte populations appears to be due to recent changes in the land use practices of Anglo-American settlers, rather than to climatic changes or Indian exploitation.

Some of the possible factors that have contributed to this decline in numbers of tubers and bulbs would include livestock grazing; fire suppression, urban development, agriculture, introduced weeds, changes in water regimes, and commercial overexploitation. Furthermore, the recent introduction of feral pigs (*Sus scrofa*) to California has undoubtedly created ecological effects on different ecosystems which have hardly been studied by scientists (Barrett 1990). An overabundance of feral pigs, an animal not native to California, may lead to a decrease in bulb populations, since pigs do not discriminate between bulbs and bulblets, and intense rooting might decrease the productivity of wild bulbs. Fire suppression policies that have been enforced for decades in numerous ecosystems also may have increased shade and plant competition and decreased the population size of some geophytes. In areas subjected to urban development or agriculture, bulbs and corms completely disappear; the uprooting caused by plows and trac-

tors allows them to desiccate in the sun. Perhaps these geophytes can only survive exposure to moderate amounts of disturbance.

The possibility that the historical levels of rhizome, bulb, tuber, and corm production that were achieved at well-known subsistence locations may have been mediated by human intervention is particularly intriguing (Anderson and Nabhan 1991). Although they did not realize it, the colorful landscapes of California that so impressed early writers, photographers, horticulturalists, and landscape painters were essentially edible landscapes. *Plagiobothrys* spp., *Calandrina* spp., and yellow composites were relished for their seeds; *Amsinckia*s were harvested for their greens; mariposa lilies (*Calochortus* spp.), blue camas (*Camassia quamash*), yampah (*Perideridia* spp.), and brodiaeas (*Dichelostemma* spp., *Triteleia* spp., and *Brodiaea* spp.) were dug for their delectable bulbs—and all were harvested in quantities that seem unimaginable today.

According to many ethnographic accounts, bulbs and corms were gathered in great abundance. Latta (1977:45) stated that among the Yokuts, several varieties of Brodiaea were dug and "eaten by the ton." The lemon-yellow globe tulip (*Calochortus pulchellus*) —which is now rare and endangered—was common in open woods and was gathered in "considerable quantity" by the Indians of Mendocino County (Chesnut 1902:323). Uldall and Shipley (1966) recorded an abundance of blue camas that was gathered by the Nisenan in the early days.

Traditional gathering sites were visited annually, over long periods of time, apparently without exhausting the resources (Latta 1977; Gayton 1948; Pilling 1978). There are also references to gathering tracts that were specifically owned and maintained by particular families; the Atsegewi, for example, laid claim to particular patches of edible roots (Kroeber 1925:317). Sometimes a gathering site even carried the name of the plant that was being gathered. ***Ket'-en chou*** was a name given to a valley in Mendocino County because of the large numbers of ***Ket'-en*** (blue camas) plants that occurred and were gathered there by the Wailaki (Chestnut 1902:327). One of the brodiaeas was so important to the Wiyot as a food source that its name was given to both Lindsey Creek and to a camp site near its head where many of the corms were gathered at certain seasons (Loud 1918:234). These and similar accounts suggest the abundance and density of geophytes in the places where they were gathered.

Chestnut (1902:323,329) reported that gathering sites contained up to 200 Ithuriel's spears (*Triteleia laxa*) per square foot and stated that "great tracts" of mariposa lilies (*Calochortus venustus*) grew on open hillsides throughout Mendocino County and furnished "potatoes" to the Indians. Pedro Font noted in 1776 that great quantities of soaproot (*Chlorogalum pomeridianum*) were eaten by the Hulpumne Yokuts in the Central Valley: "The amole is the food which most abounds, and the fields along here are full of it" (Latta 1977:65). One would expect that the continual use of a traditional site over time would cause depletion of the bulb resources. Thus, this phenomenon of plant abundance at traditional gathering sites suggests that the gathering was judicious and involved management, and therefore probably had benign or even beneficial effects upon populations of geophytes.

GEOPHYTES AND DISTURBANCE

Virtually every ecosystem in California has evolved in association with disturbance (Christensen 1988). Lightning fires, tree windfalls, herbivory, landslides, and flooding are some of nature's processes that not only destroy but renew vegetation. Studies in South Africa, where Mediterranean ecosystems similar to those found in California exist, have shown that geophytes often thrive in disturbed environments. Certain geophytes, such as *Micranthus* spp., have evolved specific adaptations in response to being a food source for mole rats (*Bathyergus* and *Cryptomys* spp.). Ecological field research has demonstrated that highly palatable corms are harvested by mole-rats, eaten on route to the burrow, and cached for later eating. In the process, some of the cormlets sited on the stem above the corm as well as some of the corm segments are dispersed, thus ensuring the plant's future existence. Some scientists have, in fact, hypothesized that the species-rich geophyte vegetation of the western Cape might be partially a result of the activities of burrowing rodents (Lovegrove and Jarvis 1986).

In California numerous mammals regularly dig up the bulbs, corms, and tubers of herbaceous plants, including black bears (*Ursus americanus*), mule deer (*Odocoileus hemionus*), exotic pigs, and pocket gophers (*Thomomys* spp.) (Chestnut 1902; De Nevers and Goatcher 1990; Hunt 1992). Many of these geophytes reproduce vegetatively through offsets, some of which may be effectively dispersed by animals while they are in the process of eating the mature, larger corms or bulbs. George Works and others have observed areas where wild pigs have rooted; the bulbs, a year or two later, "are thicker than they ever were" (Work 1995). The late James Roof put forth the hypothesis that pocket gophers had a mutualistic relationship with blue dicks (*Dichelostemma capitatum*), since gophers were scattering the cormlets and thinning the beds, which in turn benefited the dispersal of the plant, controlled overpopulation, and reduced the risk of consequent nutrient depletion (Roof 1981). An insightful Karuk story published by J.P. Harrington actually connects the gopher with the spread and abundance of tubers:

> "Sometimes they [the Karuk] see at some place a lot of Indian potatoes and then they dig in under. Behold there are lots underneath... And in the myths Gopher.... packed ***ŭ pva'amáy'av*** [tubers] around; he packed them around. ***A'ikrə́"n*** [sugar loaf bird] brought them in from Scott Valley, he brought some in for his younger brother. He said to his young brother: 'do not let my wife see you when you are eating the ***ŭ pva'amáy'av*** [tubers]...' And that is why he used to eat it upslope, upslope then, Gopher. It came up, every place he went; those were the only places where there was ***ŭ pva'amáy'av*** [tubers], the places where he went" (Harrington 1932:66).

Could Native American digging practices have effectively mimicked the disturbance regimes of other mammals? If so, the gathering of geophytes with a digging stick may have been part of a mutualistic relationship, in which both the gatherer and the plant were symbionts; in other words both benefited. The image of California Indians as incipient horticulturalists conflicts sharply with the old stereotype that was still in effect and promoted by anthropologist Alfred Kroeber as late as 1961:

"As the Indians of California, except for two or three tribes at the southeastern border, did not practice agriculture and in fact knew nothing about it, their situation was very different. Where one gathers wild foods or depends on hunting and fishing, even where the land is fertile and fruitful, it is obvious that its resources must in time be exhausted. There is no replanting, no restocking, there is no breeding; and so the human population is bound to scatter out increasingly to find its food" (Kroeber 1961:90).

HORTICULTURAL PRACTICES

Ecologists have tended to ignore Native Americans as an ecological force actively shaping plant communities. However, plant associations are the consequence of historical processes, and it therefore behooves ecologists and land managers to elucidate the role of Native Americans as an additional source of disturbance in the landscape. Early anthropologists created a simple dichotomy in which domesticated plants were seen as "cultivated," while all wild plants were labeled "not cultivated" (Holmes 1909). Recently scholars such as Ford (1985) and Harris (1989) have proposed that plant-human interactions in the area of prehistoric food production be conceptualized as a continuum, where the focus is upon the diversity and interrelations of activities by means of which people have, in the past, exploited both wild and domestic plants and animals. This new perspective emphasizes a full spectrum of plant species ranging from wild, to cultivated, to semi-domesticated, to domesticated.

While most California Indian tribes did not practice domesticated agriculture, they utilized a variety of horticultural techniques—such as burning, pruning, sowing, tilling, and selective harvesting—which nevertheless had ecological effects at different scales of biological organization. If ethnobiologists could decipher the ecological principles embedded in these land management systems, it might help to restore disturbance regimes that maintained particular ecosystem states and drove biological diversity (Anderson and Moratto 1996). If many geophytes were adapted to indigenous disturbance regimes, the alteration or removal of those regimes might have caused populations to dwindle.

The disturbance of geophyte populations through small and large mammal activity, lightning fires, or landslides, probably activates new vegetative reproduction, increasing the size and quantity of new bulblets and cormlets. Various California Indian tribes took advantage of this plant adaptation, using human-made disturbances such as burning and tillage to stimulate growth in fragments left after harvesting (Figure 6). Geographer Carl Sauer got it half right when he called the root digging of native people "unplanned tillage" (Sauer 1967:178). Tillage is defined as the removal of earth during the harvesting of underground perennial plant organs (e.g., roots, rhizomes, corms, bulbs), often followed by the subsequent dividing of these organs and the leaving of individual fragments in the soil (Anderson and Moratto 1996). Tillage may have resulted in the enhancement of certain plants, both in quality and in numbers. The digging of edible underground parts also may have "thinned" the resource, separating smaller individuals and activating their growth, thus increasing the size of the tract, aerating

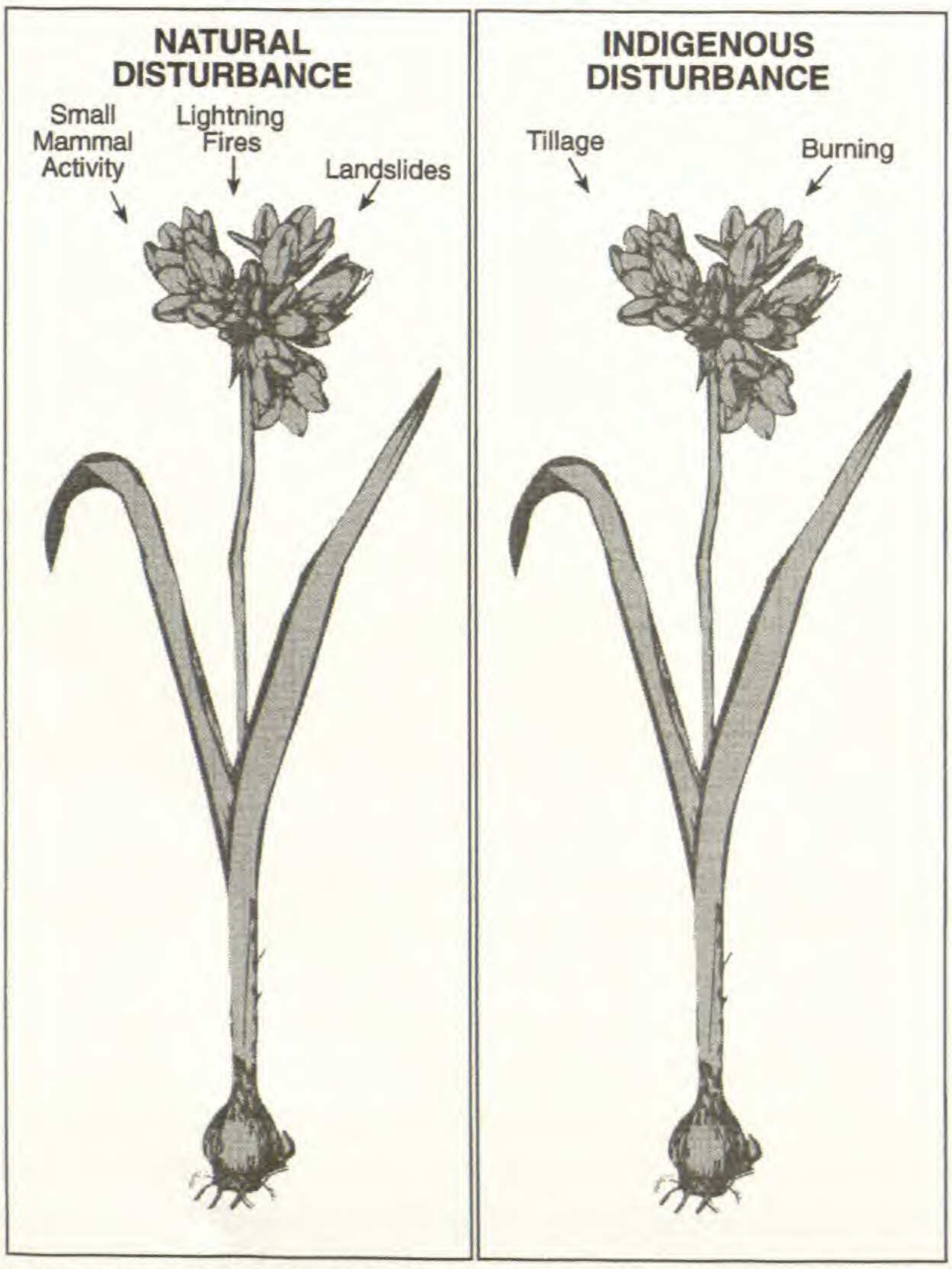

FIGURE 6.—It is hypothesized that indigenous burning and scattering of the small offsets while digging for bulbs and tubers closely mimicked natural disturbance regimes with which geophytes coevolved.

the soil, reducing weed competition, and preparing the seedbed for increased seed germination rates (Peri 1985).

Conversations with elders in various tribes in the Sierra Nevada make it clear that their procedures, passed down through millennia, were intentional—were and continue to be planned tillage. There were, in fact, five major types of activities that were designed to ensure future bulb and corm production: (1) the conscious replanting of bulblets or cormlets; (2) the sparing of whole plants; (3) harvesting after plants had gone to seed; (4) burning selected areas; and (5) irrigation. Today, for example, some individuals of the North Fork Mono and Chukchansi Yokuts tribes separate the smallest bulbs of wild onions and rebury them to insure that more will grow next year. At least one person of Yokuts and Western Mono descent breaks off soaproot plants at their roots so they will grow into new plants (Anderson, interview notes, unpublished). When harvesting different *Dichelostemma* and *Brodiaea* spp., some Wukchumni Yokuts in Tulare County and the Sierra foothills spare half of the plants in a cluster and remove the "babies" to put back in the ground (Anderson 1992).

The deliberate management of geophyte populations has been documented to some extent in the historical literature. Peri and Patterson (1979) reported that the Cloverdale and Dry Creek Pomo cultivated "root-crops" by loosening the earth with their digging sticks, which mixed surface nutrients into the ground, improved drainage and allowed a better absorption of moisture during the growing season; thus, the growth and abundance of bulbs and corms were enhanced. The Cahuilla Indians in southern California gathered the mature corms of blue dicks but were careful to replant the cormlets (Bean and Saubel 1972). The Yurok, Hupa, and Tolowa who still harvest the bulbs of *Lilium* spp. in northwestern California, selectively harvest the biggest bulbs, replanting small bulbs for later harvesting (Heffner 1984). The Northern Maidu people purposefully left some plants of wild carrot (*Perideridia* spp.) and camas to ensure future production (Potts 1977). The Luiseno in southern California transplanted certain tubers, as well as bulbous plants such as *Allium* spp. (Shipek 1977). J.P. Harrington recorded in his field notes that the Chumash on Santa Rosa Island gathered the corms of blue dicks after the plants had died back, taking only the corms and leaving the seedheads behind, thus ensuring that seed remained at the site (Timbrook 1993:56). The Owens Valley Paiute

FIGURE 7.—Photograph taken in 1931 by J.P. Harrington showing a Wintu couple, Rosa Charles and Billy George, digging for yampah (*Perideridia* spp.). Photo courtesy of the Santa Barbara Museum of Natural History. Yampah fields like this one were periodically burned by different tribes to recycle nutrients, decrease plant competition, encourage the growth of yampah, and keep surrounding vegetation from encroaching.

practiced ditch irrigation on the east side of the Sierra Nevada; a number of native plants were artificially watered to increase their productivity and abundance, including blue dicks (Lawton et al. 1993).

Habitats, as well as specific plant populations, were manipulated with deliberately-set fires. Areas were burned to reduce plant competition, facilitate gathering, recycle nutrients, and increase the size and number of bulbs and tubers (Figure 7). Bulbs may lie dormant for a decade or more waiting for fire or other favorable environmental conditions before flowering.

Schoolcraft (1860) reported that the Indians burnt off the grass in northwestern California "for the purpose of collecting aniseed [very likely *Perideridia* spp.] with greater ease." Baxley, during a visit to Yosemite Valley in the 1860s, witnessed such an indigenous fire: "Areas of *haukau* [unidentified species] were fired in Yosemite Valley by the Miwok for the purpose of clearing the ground to more readily obtain their winter supply of these 'sweet potato roots'" (Baxley 1865). Shepherd (1989:411) recorded for the Wintu that, "Where the ground has been burned, wild potatoes grow in bunches and ripen big."

Peri and Patterson (1979) reported that the Pomo deliberately burned areas to increase the production of bulbs and corms. The Chumash, Miwok, Western Mono, and Pomo burned certain areas in the fall of the year to promote the growth of edible bulbs, reduce plant competition, and keep woody vegetation from encroaching (Lewis 1993). Today, at least one elder of Chukchansi Yokuts/Miwok descent in the Sierra Nevada recalls burning areas for "wild potatoes" (*Perideridia* spp. and *Sanicula* spp.) in August or September in ponderosa pine forests and meadows; the burning was done to fertilize the ground and to make the tubers bigger and more plentiful. Two Western Mono elders recall the burning of areas in the Sierra foothills in autumn to increase the numbers of wild onions and tubers of *Sanicula tuberosa* (Anderson, interview notes, unpublished).

One of the indigenous peoples' motivations in setting frequent fires in the mixed coniferous forests of the Sierra Nevada was probably to promote the diversity, density, and abundance of many kinds of geophytes. Some of the edible tuberous and bulbous plants that grow in open forests, and which might have benefited from light surface fires, include *Sanicula bipinnatifida, Sanicula tuberosa,* and *Balsamorhiza sagittata,* gathered by the Sierra Miwok; *Sanicula tuberosa* and *Calochortus monophyllus,* gathered by the Maidu; *Calochortus venustus,* gathered by the Sierra Miwok and the Tubatulabal; and *Lilium pardilinum,* gathered by the Sierra Miwok and the Maidu (Anderson, interview notes, unpublished; Barrett and Gifford 1933; Duncan 1963:60; Powers 1877:424).

REGIONAL PATTERNS OF GEOPHYTE USE

The successful exploitation of edible geophytes over long periods of time reflected not only cultural adaptations relating to choices of foods, but an understanding of plant adaptations to natural disturbance regimes as well. Comparative analyses of plant uses between tribes may reveal repetitive patterns of utilization of specific plant species across linguistic boundaries and between geographic regions. Species that were commonly managed over large geographic areas could be investigated further to discover details about former indigenous distur-

bance regimes and about the structure and function of the particular culturally-modified ecosystem. By understanding the plant's place in the successional sequence and ecology of the ecosystem, and its response to different disturbance regimes, it may in turn be possible to elucidate the ecological or cultural processes that drive biological diversity and create specific ecosystem states. By managing for specific ecosystem states it may be possible to bring back associated plant species, which in turn will attract wildlife that would thrive in the altered ecosystem.

One species that was commonly exploited for its edible corm in California was blue dicks. Blue dicks had a wide historical use as a food (Figure 6). While a majority of tribes in California probably ate the corms of this plant, anthropologists often did not identify blue dicks to the species level—frequently lumping

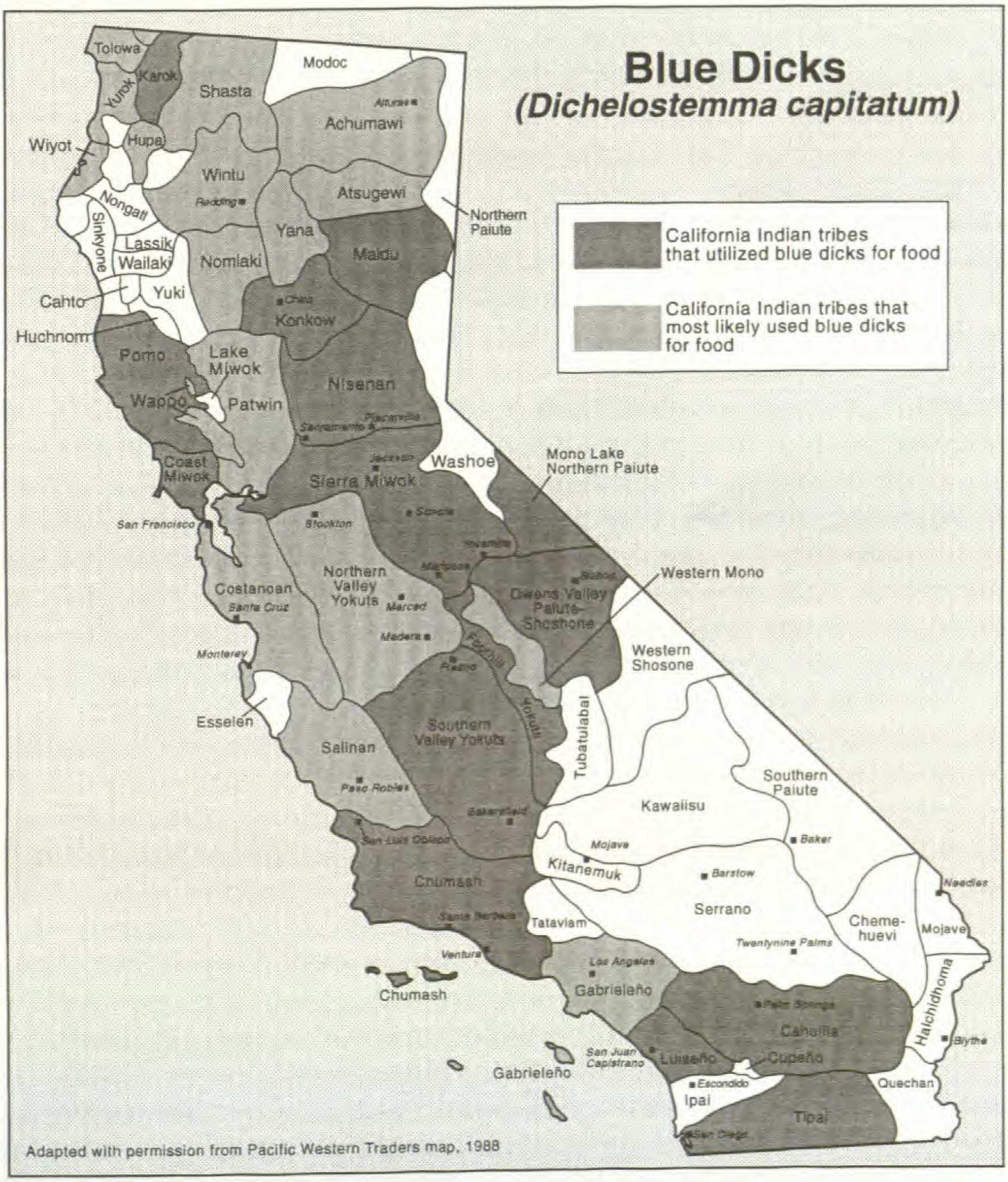

FIGURE 8.—California map showing the widespread use of one geophyte species, blue dicks (*Dichelostemma capitatum*), that crosses linguistic and geographic boundaries.

them under the generic term "Brodiaeas". Blue dicks were once categorized in the genus *Brodiaea,* at a time when many anthropologists were conducting their ethnobotanical research, and they were usually identified by systematists as *Brodiaea capitata* or *Brodiaea pulchella*. Therefore, the map (Figure 8) indicates tribes where utilization is inferred because the ethnographer only recorded the common name, or identified plants at the genus, but not species level.

If the same plant species was used by many cultural groups, as was the case with blue dicks, it may mean that the utilization was an ancient one—as the diffusion and adoption of a specific plant use across cultures takes time. Even more importantly, the wide utilization may point to a species that gains a reproductive advantage when managed by humans, making it an extremely attractive, sustainable food source, and partially explaining its adoption by many different societies. Harvesting and manipulating plant populations in certain ways created predictable ecological outcomes that enabled humans to increase the concentration of plant resources, and thereby intensify their resource use in defined areas.

POTENTIAL ECOLOGICAL EFFECTS

Species level.—Through human selection, protection, and replanting, certain geophyte species may have undergone genetic change. It is now recognized that genetic changes in plants can occur in relatively short amounts of time through human selection, as in the case of devil's claw (*Proboscidea parviflora*), a recently domesticated and diffused Native American crop (Nabhan and Rea 1987). The excavation of plants with vegetative reproductive parts and the replanting of such parts would tend to select for specific genotypes that would hold up well to (and perhaps even thrive under) human harvesting regimes. Human selection would favor mature corms and bulbs that produced the greatest number of cormlets and bulblets, because by intentionally replanting them, they would also leave the greatest number of offspring. Those genotypes that were easily uprooted while remaining completely intact—with all roots and vegetative structures—or that produced few vegetative offsets, would have been selectively extirpated or severely reduced in numbers in the population.

The potential linkage between a society's horticultural practices and utilization of particular plant species and the cultural selection pressures exerted on those species has not been sufficiently studied for edible underground swollen stems. However, the low variability in particular populations of *Camassia quamash* in California, for example, may be due to the selective harvesting practices of different tribes (Susan D'Alcamo, personal communication 1997).[2] One potentially fruitful avenue of future research might involve a comparison of the morphological and genetic variation in populations of a native species gathered in several different tribal territories with the different harvesting and management regimes of each tribe.

Population level.—The numbers, sizes, and densities of favored geophyte species were probably heightened through human intervention. A regime of repeated burning not only augmented useful plant parts but in many cases increased the size of the gathering tract. Because edible plants such as wild onions are often

extremely small, and tribes required large quantities for consumption and storage, gathering sites were probably managed for high population densities, and plants were therefore encouraged to grow in a clumped or aggregated pattern. Dense populations of plant species at known collection sites would significantly reduce labor costs and eliminate the uncertainty and time involved in a random or haphazard search for useful plants in the landscape.

Community level.—Vegetation dominated by coniferous forest was often managed for maximum vertical structural complexity, which heightened biodiversity and encouraged a variety of geophytes to grow in the understory. The forests of California were manipulated to create areas with a tree, shrub, and herbaceous physiognomy, giving the forests a layered effect. The herbaceous component of these plant communities was extremely important, and it was carefully managed to provide foods, as well as basketry, cordage, and medicinals (Anderson, interview notes, unpublished). The growth of small trees and brush thickets was discouraged by means of frequent burning, and sometimes by hand weeding (Essene 1942; Dixon 1905:201; Drucker 1937). Frequent burning in conifer forests encouraged widely-spaced, large-diameter trees, creating a vertical structure characteristic of old-growth forests. Today, in many of our national forests where fire is excluded, canopy coverage has reached maximum values, and the understory is impoverished in plant species diversity—in part due to the small number of species that can tolerate extreme shade (Pickett 1976).

Periodic burning occurred within many other plant community types, creating large and small openings that favored populations of desired plant species. An emphasis was placed on encouraging many sun-loving plants. The spatial effect of encouraging specific populations of plant species to grow at numerous gathering sites was a high degree of "patchiness," with plant species in varying successional stages occurring within more homogeneous, naturally-occurring plant community types. Studies of chaparral, oak woodland, and coniferous forest communities have shown that geophyte species richness after fire or other disturbances reaches its maximum values within a few years and then dwindles as the shrub or forest canopy closes (Keeley 1981; Spies and Franklin 1989). Previous studies have emphasized the fact that shade-intolerant plants are the most useful in terms of indigenous needs (Lewis 1993; Reynolds 1959). The result of regular, light-surface burning was maximal biodiversity.

Landscape level.—Landscapes can be viewed as mosaics of ecosystems, generated by disturbance (Pickett 1976). Native Americans complemented natural processes and introduced systematic disturbance in order to maximize plant community diversity. They recognized that each plant community type harbored a unique array of plant and animal species and that some plant community types, while covering small land surface areas, harbored extremely useful and varied plant life. These communities were maintained in a holding pattern rather than being allowed to succeed naturally into a new plant community type. Some examples of special plant community types that contained abundant geophytes and were burned to maintain and in some cases expand their extent would be valley grasslands, montane meadows, and coastal prairies (Anderson 1993).

PROPOSED METHODS FOR RECONSTRUCTING INDIAN-GEOPHYTE RELATIONSHIPS

A full understanding and explication of wild plant production systems will be achieved only through the development of a better rapprochement between the social, historical, and biological sciences than presently exists (Blackburn and Anderson 1993). It would require the sustained and cooperative efforts of scholars using both human- and land-centered avenues of research. Human-centered approaches would involve ethnobotanical studies which record the uses, storage, preparation, manufacturing, gathering methods, and management techniques employed with wild species, through interviews and participant observation. The actual monitoring and detailed analysis of the dynamics of plant production sites, the simulation of these techniques through a series of experiments, the study of the natural history of the wild species, and the potential application of this information to modern wildland management, all comprise facets of a more land-centered approach. These different approaches are explained more fully below.

Ethnobotanical studies.—More ethnographic studies of native peoples that explore the multidimensionality of traditional ecological knowledge with respect to one focal plant species are needed. Native people are the repositories of generations of keen observation and diligent experimentation that has finely tuned their relationships with nature. In some cases indigenous people are still practicing native plant management adjacent to their homes. Such studies entail interviewing Native Americans in a cultural context, usually at their homes. Questions are presented in a non-technical language, yet are still designed to elicit detailed responses that provide cultural information about the plant's manipulation that is related to perceived biological and ecological outcomes. This information, if detailed enough, will be useful to the fields of plant ecology and conservation biology. Harvesting and management information, for example, should be collected with regard to such environmental variables as season, frequency, intensity, scale, and pattern of disturbance. Cultural objectives for harvesting and management—such as recycling nutrients, decreasing insect pests, increasing fruit production, or removing accumulated dead material—need to be meticulously recorded.

Assembling a reference collection of slides, photographs, and herbarium specimens of plants for consultant identification and recall of harvesting, management and use information is extremely helpful in substantiating and enriching information gained from oral interviews. In addition to interviews, it is important to view native consultants in different situations, such as out in the field in direct contact with nature. Often sites are chosen for special environmental conditions including level of light, moisture, plant associations, soils, and elevation. Recording these site criteria demonstrates the finely-grained distinctions Native Americans make in their selection of suitable areas for plant collection.

Observational studies.—The natural history of most native plant species is not well known. According to the eminent biologist E.O. Wilson, the biodiversity in our temperate forests, for example, is fragile and still poorly understood (Wilson 1993). Therefore, observational studies that give the researcher solid information about a plant's life history characteristics, pollination ecology, seed dispersers, and other essential aspects of the species' biology and ecology are a very impor-

tant complement to ethnobotanical research. Additionally, such studies investigate the environmental conditions under which the plant grows, such as soil types, moisture regimes, plant associations, slope, aspect, and light requirements.

Greenhouse and field experiments.—Once enough descriptive information is available about harvesting and management strategies for geophytes, and observational studies have been conducted to learn about the natural history of the species, this information would form a basis for the design of experiments which would empirically test the effects of various gathering and horticultural techniques (specifically tillage, burning, and cormlet replanting) on the growth and productivity of particular native plants, as well as on biodiversity and habitat heterogeneity in specific geographic regions (Figure 9). The experimental approach has the advantage of focusing on specific questions and/or hypotheses relating to the effects of harvesting strategies and indigenous horticultural practices on specified features or characteristics of individual plants, populations, or plant communities. They require quantitative data which are subjected to appropriate analyses to test stated hypotheses and/or answer relevant questions. Because of the complexity of the ecological processes concerned, this approach would require long-term experiments carefully designed and constrained to discern patterns and levels of effects with reasonable confidence.

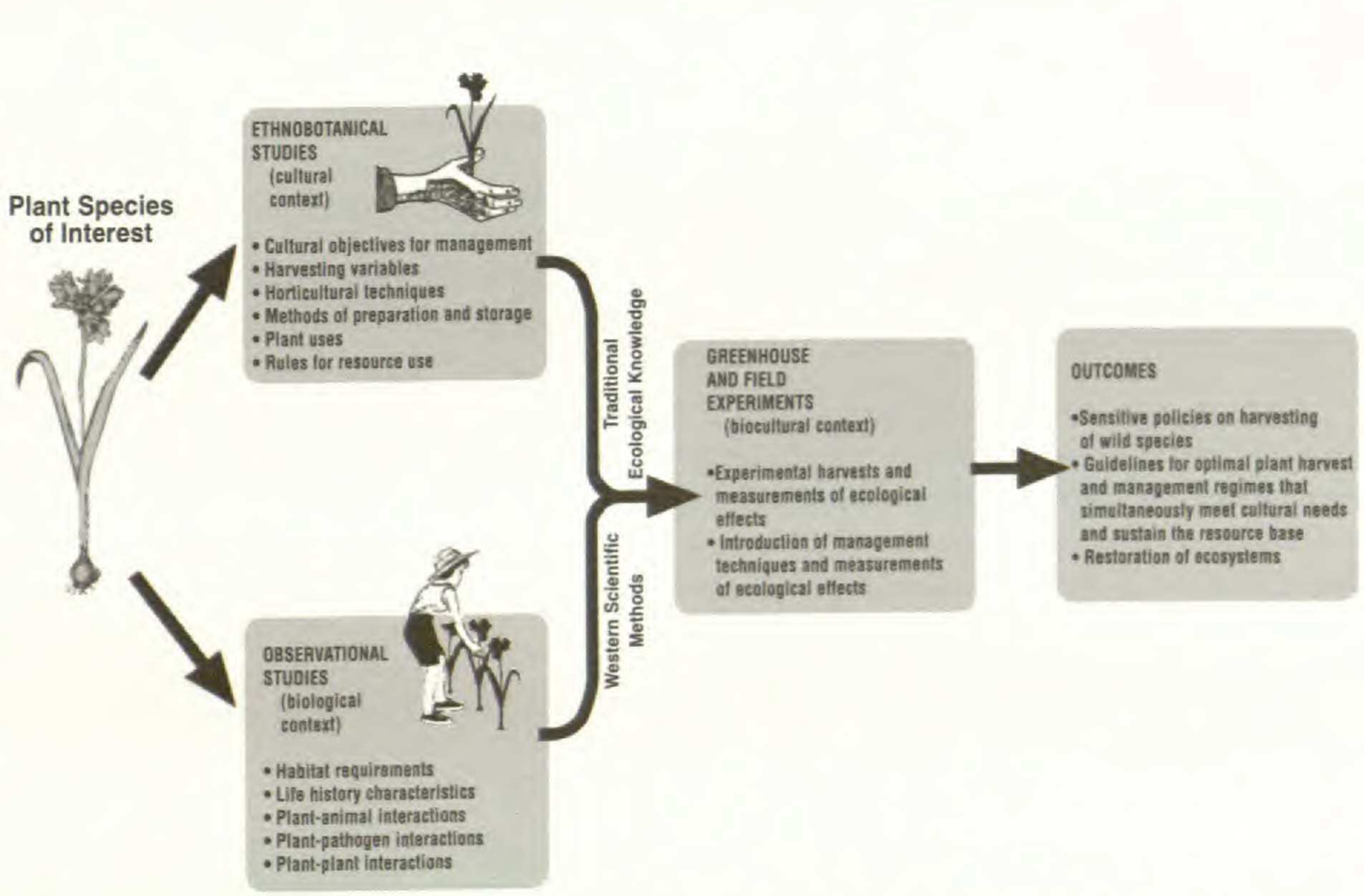

FIGURE 9.—Three types of research that are needed to reconstruct the details of interactions between indigenous peoples and geophytes. The descriptive and interpretive evidence of these systems provided by ethnobiologists, and natural history information provided from observational studies, form a logical basis for the development of experiments and the testing of hypotheses to objectively assess the interrelations and impacts of indigenous cultural practices on plant resource productivity and vegetation.

CONCLUSIONS

The cultivation of geophytes by burning, sparing plants, replanting of propagules, and harvesting after seeding has been an important element in comprehensive indigenous land management systems that have been in place for millennia, and that have encompassed many California wildland areas. Indigenous women, as the major plant harvesters, played a substantial role in shaping California's landscapes, producing ecological consequences at several levels of biological organization. It is hypothesized that women's tillage activities mimicked the natural disturbances with which geophytes coevolved, and that women played an ecological role that is now absent from many wildlands, where Native Americans usually can no longer harvest and manage plants. Their management systems need to be studied and described through ethnobotanical research; then interpreted and experimentally mimicked to elucidate indigenous disturbance regimes and ecological effects. A logical outgrowth of these studies would be the restoration of ecosystems with all of their former biological diversity, as well as the development of sensitive policies regarding sustainable wild harvesting (Anderson 1996; Figure 9). Some areas would greatly benefit from the reintroduction of management and harvesting regimes that authentically mimic ancient indigenous interactions.

NOTES

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LITERATURE CITED

ANDERSON, M. KAT. n.d. Unpublished Western Mono, Foothill Yokuts, and Sierra Miwok interview notes.

ANDERSON M. KAT. 1992. At home in the wilderness. News from Native California Vol. 6(2). Berkeley, California.

ANDERSON M. KAT. 1993. Native Californians as ancient and contemporary cultivators. *In* Before the Wilderness: Environmental Management by Native Californians, T. C. Blackburn and M. K. Anderson (editors). Ballena Press. Menlo Park, California.

ANDERSON M. KAT. 1996. Tending the wilderness. Restoration & Management Notes 14(2):154-166.

ANDERSON, M. KAT and MICHAEL J. MORATTO. 1996. Native American Land-Use Practices and Ecological Impacts. Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II. Assessments and Scientific Basis for Management Options. Centers for Water and Wildland Resources, University of California, Davis.

ANDERSON M. KAT and GARY P. NABHAN. 1991. Gardeners in Eden. Wilderness Magazine 55(194):27-30.

BARRETT, REGINALD H. 1990. Pigs and oaks. Fremontia 18(3):82.

BARRETT, SAMUEL A. and EDWARD W. GIFFORD. 1933. Miwok material culture: Indian life of the Yosemite region. Bulletin of the Milwaukee Public Museum 2(4):120-377. Reprinted by the Yosemite Natural History Association.

BAXLEY, WILLIAM H. 1865. What I Saw on the West Coast of South and North America and at the Hawaiian Islands. D. Appleton & Company, New York.

BEAN, LOWELL J. and KATHERINE S. SAUBEL. 1972. Temalpakh: Cahuilla Indian Knowledge and Usage of Plants. Malki Museum Press, Morongo Indian Reservation, Banning, California.

BLACKBURN, THOMAS C. and M KAT ANDERSON (editors). 1993. Introduction. Pg 15-25 *in* Before the Wilderness: Native Californians as Environmental Managers. Ballena Press, Menlo Park, California.

BYE, ROBERT A. 1985. Botanical perspectives of ethnobotany of the greater Southwest. Economic Botany 39(4):375-386.

CHESTNUT, V. K. 1902. Plants used by the Indians of Mendocino County, California. Contributions from the United States National Herbarium, 1900-1902. Vol 7:295-422. Government Printing Office, Washington, D.C. Reprinted in 1974 by the Mendocino County Historical Society Inc., Fort Bragg, California.

CHRISTENSEN, NORMAN L. 1988. Succession and natural disturbance: Paradigms, problems, and preservation of natural ecosystems. Pp. 62-86 *in* Ecosystem Management for Parks and Wilderness, J. K. Agee and D. R. Johnson (editors). University of Washington Press, Seattle.

COLLIER, MARY E. T., and SYLVIA B. THALMAN. 1991. Interviews with Tom Smith and Maria Copa: Isabel Kelly's ethnographic notes on the Coast Miwok Indians of Marin and southern Sonoma Counties, California. Miwok Archeological Preserve of Marin Occasional Paper Number 6, pg 121. San Rafael, California.

DE NEVERS, G. and B. GOATCHER. 1990. Feral pigs kill knobcone pines. Fremontia 18(1):22-23.

DIXON, ROLAND B. 1905. The Northern Maidu. Bulletin of the American Museum of Natural History 17(3):119-346.

DRIVER, HAROLD E. and WILLIAM C. MASSEY. 1957. Comparative studies of North American Indians. Transactions of the American Philosophical Society 47(2):165-456.

DRUCKER, PHILIP. 1937. Culture element distributions, V: Southern California. University of California Anthropological Records 1(1):1-52.

DUNCAN, JOHN W. 1963. Maidu ethnobotany. Master's thesis (Anthropology), California State University, Sacramento.

ESSENE, FRANK J. 1942. Culture element distributions, XXI: Round Valley. University of California Anthropological Records 8(1):1-97.

FORD, RICHARD I. 1985. The processes of plant food production in prehistoric North America. Pp 1-18 *in* Prehistoric Food Production in North America, Richard I. Ford (editor). Museum of Anthropology, University of Michigan, Ann Arbor.

FOWLER, CATHERINE S. 1986. Subsistence. Pp 64-97 *in* Handbook of North American Indians, Vol. 11, Great Basin, Warren L. D'Azevedo (editor). Smithsonian Institution, Washington, D. C.

GAYTON, ANNA H. 1948. Yokuts and Western Mono ethnography. University of California Anthropological Records 10(1-2):1-32.

GOTT, BETH. 1983. *Murnong—Microseris scapigera*: A study of a staple food of Victorian aborigines. Australian Aboriginal Studies 2:2-18.

HARRINGTON, JOHN P. 1932. Tobacco among the Karuk Indians of California. Smithsonian Institution Bureau of American Ethnology Bulletin 94. United States Government Printing Office, Washington, D. C.

HARRIS, DAVID R. 1989. An evolutionary continuum of people-plant interaction. *In* Foraging and Farming: The Evolution of Plant Exploitation, David R. Harris and Gordon C. Hillman (editors). Unwin Hyman, London.

HEFFNER, KATHY. 1984. Following the smoke: Contemporary plant procurement by the Indians of northwest California. Unpublished report, Six Rivers National Forest, Eureka, California.

HEIZER, ROBERT F. and ALBERT B. ELSASSER. 1980. The Natural World of the California Indians. University of California Press, Berkeley.

HOLMES, G.K. 1909. Aboriginal agriculture—the American Indians. Pg 24-39 *in* Cyclopedia of American Agriculture, L. H. Bailey (editor). The MacMillian Co., London.

HUNN, EUGENE S. 1981. On the relative contribution of men and women to subsistence among hunter-gatherers of the Columbia Plateau: A comparison with *Ethnographic Atlas* summaries. Journal of Ethnobiology 1:124-134.

———— and DAVID H. FRENCH. 1981. *Lomatium*: A key resource for Columbia Plateau subsistence. Northwest Science 55:87-94.

HUNT, JODEE. 1992. Feeding ecology of valley pocket gophers (*Thomomys bottae sanctidiegi*) on a California coastal grassland. American Midland Naturalist 127:41-51.

KARI, PRISCILLA R. 1987. Tanaina Plantlore. *Dena'ina K'et'una*: An Ethnobotany of the Dena'ina Indians of Southcentral Alaska. National Park Service Alaska Region, Anchorage.

KEELEY, STERLING C., JON E. KEELEY, STEVE M. HUTCHINSON, and ALBERT W. JOHNSON. 1981. Postfire succession of the herbaceous flora in southern California chaparral. Ecology 62(6):1608-1621.

KELLY, ISABEL T. 1932. Ethnography of the Surprise Valley Paiute. University of California Publications in American Archaeology and Ethnology 31(3):67-210.

KROEBER, ALFRED L. 1925. Handbook of the Indians of California, Bulletin 78. Bureau of American Ethnology of the Smithsonian Institution. Republished 1976 by Dover, New York.

————. 1961. The nature of land-holding groups in aboriginal California. Reports of the University of California Archaeological Survey, No. 56. Berkeley.

LATTA, FRANK F. 1977. Handbook of Yokuts Indians. Bear State Books, Santa Cruz, California.

LAWTON, HARRY W., PHILIP J. WILKE, MARY DEDECKER, and WILLIAM M. MASON. 1976. Agriculture among the Paiute of Owens Valley. The Journal of California Anthropology 3(1):13-50.

LEWIS, HENRY T. 1993. Patterns of Indian burning in California: ecology and ethnohistory. Pp. 55-116 *in* Before the Wilderness: Environmental Management by Native Californians, Thomas C. Blackburn and Kat Anderson (editors). Ballena Press, Menlo Park, California.

LOUD, LLEWELLYN L. 1918. Ethnography and archaeology of the Wiyot territory. University of California Publications in American Archaeology and Ethnology 14(3):221-436.

LOVEGROVE, B. G. and J. U. M. JARVIS. 1986. Coevolution between mole-rats (Bathyergidae) and a geophyte, *Micranthus* (Iridaceae). Cimbebasia, Windhoek, South Africa.

McMILLIN, JAMES, H. 1963. The aboriginal human ecology of the Mountain Meadows area in southwestern Lassen County, California. Master's thesis (Social Science), California State University, Sacramento.

NABHAN, GARY P. and AMADEO REA.

1987. Plant domestication and folk-biological change: the upper Piman/ devil's claw example. American Anthropologist 89(1):57-73.

NOMLAND, GLADYS A. 1938. Bear River ethnography. Anthropological Records 2(2):91-126.

PERI, DAVID W. 1985. Pomoan plant resource management. Ridge Review 4(4). Mendocino, California.

PERI, DAVID W. and SCOTT M. PATTERSON. 1979. Ethnobotanical resources of the Warm Springs Dam-Lake Sonoma project area, Sonoma County, California. Final Report of the Ethnobotanical Element of the Vegetation Management Plan Contract No. DACWO7-78-C-0043. Prepared for the United States Army Corps of Engineers, San Francisco.

PICKETT, S. T. A. 1976. Succession: An evolutionary interpretation. American Naturalist 110:107-119.

PILLING, ARNOLD R. 1978. Yurok. Pp. 649-653 in Handbook of North American Indians, Vol. 8, California, Robert F. Heizer (editor). Smithsonian Institution, Washington, D. C.

POTTS, MARIE. 1977. The Northern Maidu. Naturegraph, Happy Camp, California.

POWERS, STEPHEN 1877. Tribes of California. Contributions to North American Ethnology, III. Department of the Interior, U. S. Geographical and Geological Survey of the Rocky Mountain Region. Reprinted in 1976 by the University of California Press, Berkeley.

REYNOLDS, R.D. 1959. Effect of natural fires and aboriginal burning upon the forests of the central Sierra Nevada. Master's thesis (Geography), University of California, Berkeley.

ROOF, JAMES. 1981. Ecology in action: The great *Dichelostemma* caper. The Changing Seasons 1(3):11-13.

RUNDEL, PHILIP W. 1996. Monocotyledonous geophytes in the California flora. Madrono 43(3):355-368.

SAUER, CARL O. 1967. Early relations of man to plants. Pp 155-181 *in* Land and Life: A Selection from the Writing of Carl Ortwin Sauer, J. Leighly (ed.). University of California Press, Berkeley.

SCHOOLCRAFT, H. R. 1860. Archives of Aboriginal Knowledge. Containing all the Original Paper Laid Before Congress respecting the History, Antiquities, Language, Ethnology, Pictography, Rites, Superstitions, and Mythology of the Indian Tribes of the United States. J. B. Lippincott, Philadelphia, Pennsylvania.

SCHULZ, PAUL E. 1954. Indians of Lassen. Loomis Museum Association, Mineral., California.

SHEPHERD, ALICE. 1989. Wintu Texts. University of California Press, Berkeley.

SHIPEK, FLORENCE C. 1977. A strategy for change: The Luiseño of Southern California. Ph.D. Dissertation (Anthropology), University of Hawaii, Honolulu.

TIMBROOK, JAN. 1993. Island Chumash ethnobotany. Pp 47-62 *in* Archaeology on the Northern Channel Islands of California, Michael A. Glassow (editor). Coyote Press, Salinas, California.

TURNER, NANCY J. and HARRIET KUHNLEIN. 1983. Camas (*Camassia* spp.) and riceroot (*Fritillaria* spp.): Two liliaceous "root" foods of the Northwest Coast Indians. Ecology of Food and Nutrition 13:199-219.

WILSON, EDWARD O. 1993. Forest ecosystems: More complex than we know. Pp xi-xiii *in* Defining Sustainable Forestry, Gregory H. Aplet, Nels Johnson, Jeffrey T. Olson, and V. Alaric Sample (editors). Island Press, Washington, D. C.

WORK, GEORGE 1995. When feral pigs are good for the ecology and other heresies. Growing Native 6(5):17-20.